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## **Reconstruction of the heel, middle foot sole and plantar forefoot with the medial plantar artery perforator (MPAP) flap: clinical experience with 28 cases**

Scaglioni, Mario F ; Rittirsch, Daniel ; Giovanoli, Pietro

**Abstract:** INTRODUCTION: Defects in the weight-bearing region of the foot sole can represent a substantial restriction in quality of life and pose a challenge for reconstructive plastic surgery. The purpose of this article is to report our experience with the use of medial plantar artery perforator (MPAP) flap for reconstruction of defects of the foot sole in 3 different regions: heel, middle foot sole and plantar forefoot. PATIENTS AND METHODS: From January 2003 to May 2016, 28 patients (13 males and 15 females) with an average age of 54 years (range 12 to 84 y.o.) received reconstruction with 28 MPAP flaps. 26 flaps were harvested as pedicle perforator flaps and 2 as free perforator flaps. All flaps were raised from the ipsilateral instep area. The defect locations included the heel (20 cases), middle foot sole (4 cases) and forefoot (4 cases). The causes of reconstruction were tumors in 18 patients (64%), decubitus in 8 patients (29%) and trauma in 2 patients (7%). RESULTS: The flap sizes varied from 2.5 × 2.5 cm to 5.5 × 9.5 cm. All of the flaps survived completely after surgery, apart from one. The donor sites were all covered with a split-thickness skin graft. Follow-up observations were conducted for 4 to 12 months, and all patients had good functional recovery with satisfactory cosmetic results. CONCLUSION: The MPAP flap can be considered an optimal method of foot sole reconstruction not only for covering the weight-bearing area of the heel but also for the middle and forefoot plantar region.

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**Reconstruction of the heel, middle foot sole and plantar forefoot with the medial plantar artery perforator (MPAP) flap: clinical experience with 28 cases.**

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Running Head: Plantaris medialis artery perforator flap for total plantar foot reconstruction

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## **ABSTRACT**

### **Introduction:**

Defects in the weight-bearing region of the foot sole can represent a substantial restriction in quality of life and pose a challenge for reconstructive plastic surgery.

The purpose of this article is to report our experience with the use of medial plantar artery perforator (MPAP) flap for reconstruction of defects of the foot sole in 3 different regions: heel, middle foot sole and plantar forefoot.

### **Patients and Methods:**

From January 2003 to May 2016, 28 patients (13 males and 15 females) with an average age of 54 years (range 12 to 84 y.o.) received reconstruction with 28 MPAP flaps.

26 flaps were harvested as pedicle perforator flaps and 2 as free perforator flaps. All flaps were raised from the ipsilateral instep area. The defect locations included the heel (20 cases), middle foot sole (4 cases) and forefoot (4 cases).

The causes of reconstruction were tumors in 18 patients (64%), decubitus in 8 patients (29%) and trauma in 2 patients (7%).

### **Results:**

The flap sizes varied from 2.5 × 2.5 cm to 5.5 × 9.5 cm. All of the flaps survived completely after surgery, apart from one. The donor sites were all covered with a split-thickness skin graft. Follow-up observations were conducted for 4 to 12 months, and all patients had good functional recovery with satisfactory cosmetic results.

### **Conclusion:**

The MPAP flap can be considered an optimal method of foot sole reconstruction not only for covering the weight-bearing area of the heel but also for the middle and forefoot plantar region.

Keywords: Plantaris medialis artery perforator flap, plantar foot reconstruction, Instep flap, free flap

## **INTRODUCTION**

Soft tissue reconstruction of the foot sole has long been a reconstructive challenge not only to restore an aesthetic appearance but also to maintain function. In fact, defects of this region of the body can enormously hamper the patient's quality of life. Therefore, the choice of reconstruction of the weight-bearing plantar foot surface is very important. Due to the limited availability and mobility of the adjacent skin, defects involving the plantar foot area may require complex reconstruction procedures. One of the most important factors for skin resurfacing of the weight-bearing area of the foot sole is the provision of an adequate type of skin with similar properties, of thickness and sensitivity.<sup>1</sup>

Many techniques, such as skin graft, local flaps, local pedicle flaps and free flaps, have been already described for the reconstruction of these regions;<sup>2-13</sup> however, the reconstructive options to improve outcomes are still under discussion and there is not a supreme procedure, which is considered as a gold standard; there are only few flaps which can withstand the stresses and loads posed each and every day by a person's body weight.

Ideally, defects involving this area are optimally repaired using thin and pliable flaps. Based on basic plastic surgery principles to replace "like with like," with minimal donor site morbidity and without sacrificing a major vessel, perforator flaps designed from the instep area of the foot represent a viable option. The term "instep area" refers to the hairless non-weight-bearing medial plantar region of the foot sole centered over the medial plantar artery.<sup>14,15</sup> The medial plantar artery perforator (MPAP) flap, which is harvested from this region, is therefore ideal for the reconstruction of soft tissue defects of the foot sole with minimal donor site morbidity. The MPAP can be defined as a perforator flap based on the superficial branch of the medial plantar artery (MPA). It can be used as a pedicle or free flap.<sup>9</sup> Moreover, it contains a sensitive branch of the medial plantar nerve which supplies the instep skin area and provides a new sensation in the defect region.<sup>5,16</sup> In this article we describe our

experience using the MPAP flap for the reconstruction of defects of the heel, the middle and the forefoot sole.

## **PATIENTS AND METHODS**

Between January 2003 and May 2016, 28 patients underwent foot sole reconstructions with the MPAP flap. There were 13 male patients and 15 female patients. The average age of the patients was 54 years (range, 12 - 84 years). The causes were various and included soft tissue defect after cancer resection in 18 cases, trauma in 2 cases and pressure sores in 8 cases. The defect locations were the heel in 20 patients and the middle plantar foot and forefoot in 4 patients, respectively.

In all cases, the defect dimension and especially the weight-bearing surface precluded skin grafting and primary closure. The details of patients are presented in Table 1.

### **Surgical technique**

All flaps were designed on the medial part of the sole, the so called “instep area.” To begin, a surface marking is done in the instep area and also a preoperatively Doppler probe detected the perforators from the superficial branch of the medial plantar artery system and proved the patency of the posterior tibial artery (PTA) and dorsalis pedis artery (DPA).

Under tourniquet control without previous exsanguination, the first incision is made parallel to the abductor hallucis muscle, creating the medial border of the flap. When the flap is dissected laterally and suprafascially above the flexor hallucis muscle, several perforators of the medial plantar vessel can be readily identified through the intermuscular septum between the abductor hallucis muscle and the flexor digitorum muscle (brevis or longus) (Fig. 1).

With the use of retractors, the medial plantar vessel is clearly exposed through the intermuscular space. The perforator is deeply dissected to the division of the medial plantar vessel. The lateral border of the MPAP flap is then incised and dissected, taking care to include the perforators. The perforator arteries are always small in the MPAP flap. The diameter of the perforated artery is approximately 0.4 to 0.8 mm and the-pedicle length

approximately 4 to 6 cm. There is usually a separate branch arising from the medial plantar nerve or from the main trunk of the posterior tibial nerve. This branch again divides into 2. The medial of the 2 branches proceeds to supply the sensation of the medial side of the great toe and the lateral branch to supply the sensation of the instep area. The lateral branch supplying the instep area is easily separable from the main branch under loupe magnification. Smaller branches of the medial plantar nerve around the medial plantar aponeurosis are cut. Then, the flap is transposed or rotated in propeller fashion into the defect (Fig. 2). The donor site was covered by a split-thickness skin graft. Postoperatively, patients were maintained on strict bedrest with the foot elevated. At one week after surgery, patients were allowed to begin a dangling protocol, and at 2 weeks, patients began light weight-bearing on the operated foot with the assistance of physical therapy when indicated.

## **RESULTS**

Twenty-eight MPAP flaps were performed. The dimensions of the flap skin paddle ranged from  $2.5 \times 2.5$  cm to  $5.5 \times 9.5$  cm. The average perforator number included in the flap was 1 (range, 1–2). The mean pedicle length was 5 cm with a range of 4–6 cm.

Regarding the two free MPAP flaps, the recipient vessels were the branch of lateral plantar artery in 2 patients. The arterial anastomoses were performed in an end-to-end fashion.

All the flaps survived completely, except for one, with a success rate of 96%. One MPAP distal based flap for forefoot reconstruction was lost due to poor vascular perfusion. No arterial nor venous thrombosis occurred in the free MPAP flaps. The follow-up time ranged from 4 to 12 months (mean: 9 months). The flaps healed well and the color matches were excellent. All donor sites were covered with a split-thickness skin graft, and no early nor late complications were encountered. None of the patients complained about the donor site scar. All patients returned to their original jobs and were satisfied with the functional results and cosmetic appearance. Eventually they could also wear regular footwear. Details are shown in Table 1.

### **Case 1: Coverage of heel defect**

A 55-year-old woman sustained a weight-bearing malignant melanoma on the left heel. After a wide excision, a tumor free defect measured 5 × 5 cm was noted (Fig. 3, above left). A 5 × 5 cm pedicle MPAP flap was harvested from the ipsilateral instep area based on one perforator. (Fig.3, above right). Then the flap was transferred to reconstruct the defect (Fig. 3, below left). The donor site was covered with split-thickness skin graft from the contralateral thigh. The flap survived completely and the donor site healed uneventfully. The follow-up time was 6 months. The patient had full functional recovery with acceptable cosmetic result (Fig. 3 below right).

### **Case 2: Coverage of middle foot sole defect**

A 51-year-old man was diagnosed as malignant melanoma on the right middle foot sole. After wide excision, a tumor free defect measured 6 × 5 cm was noted (Fig. 4, above left). A 6.5 × 6.5 cm pedicle MPAP flap was harvested from the ipsilateral instep area based on one perforator. (Fig. 4, above right). Then, the flap was propelled with 90 degree of rotation to reconstruct the defect (Fig. 4, below left). The donor site was covered with split-thickness skin graft from the contralateral thigh. At the 8-month follow-up, the flap counter, color and healing were excellent. The patient had full functional recovery with acceptable cosmetic result (Fig. 4, below right).

### **Case 3: Coverage of a forefoot defect**

A 53-year-old woman was diagnosed as malignant melanoma on her right forefoot. After wide excision, a tumor free defect measured 4 × 4.5 cm was noted (Fig. 5, above left). A 5 × 5 cm pedicled MPAP flap was harvested from the ipsilateral instep area based on the distal perforator of the MPA (Fig. 5, above right). Then the flap was rotated in propeller fashion of around 180 degrees to reconstruct the forefoot defect (Fig. 5, below). The donor site was covered with split-thickness skin graft from the contralateral thigh. Postoperatively, the patient had nothing negative to report regarding ambulation or at the donor site. The follow-

up time was 6 months. The patient had full functional recovery with acceptable cosmetic result.

## **DISCUSSION**

Surgical reconstruction of soft tissue defect in the foot sole regions poses one of the greatest challenges for plastic surgery. The location of the defect enormously hampers the patient's quality of life and the peculiar anatomic structure of the plantar foot can make even a small defect a difficult task. In particular, due to the very robust and thick characteristic of the skin of this area, it can easily withstand the stresses and loads it is exposed to on a daily basis.

Many soft tissue reconstructions of these areas have been described using traditional local and free flaps, and the common aim was to use a type of skin with similar properties to the original skin in order to guaranteeing appropriate coverage and function.<sup>1,16</sup>

Since the description of the freestyle perforator concept and the perforasome theory pioneered by Wei and Mardini, the use of local perforator flaps has grown in popularity.<sup>17</sup> Hence, local perforator flaps based on the plantar medial artery have been successfully employed for plantar foot reconstruction, although the dimension of defect represents the main limitation.

As described by Attinger et al.<sup>18</sup> in 2006, the foot sole is perfused by the medial plantar artery and the lateral plantar artery providing their own corresponding angiosome. The medial plantar artery perforator (MPAP) flap is based on the perforators arising from the superficial branch of the medial plantar artery.<sup>19</sup> As it has been already reported in the literature, the perforator nourishing the MPAP flap is constant and can be found between the adductor allucis muscle and the flexor digitorum brevis muscle in proximity of the navicular bone.<sup>15,16,20</sup> However, the number of suitable perforators and their caliber has not been described. Moreover, a cutaneous nerve, branch of the medial plantar nerve, can provide sensation if incorporated within the flap.<sup>21</sup>



Due to the non-weight-bearing localization of the instep area, the MPAP flap, harvested from this region, represents an ideal method of reconstruction of soft tissue defects of the foot sole and has the great advantage that the donor site morbidity is very low.<sup>14-16</sup>

The instep flap was first described in 1981 by Harrison and Morgan for soft tissue coverage of the heel.<sup>22</sup> Thereafter, in 1983 Morrison et al.<sup>9</sup> developed a free sensory instep flap with medial plantar artery for heel defects. Since then, it has gained more and more popularity for plantar foot reconstruction, and it has been employed as free flap for defect coverage of the hand and fingers as well.<sup>23-27</sup>

It is important to clarify that the instep flap is based on the deep branch of the MPA and it is classified as a pedicle fasciocutaneous flap; contrarily, the MPAP flap is based on the perforators of the superficial branch of the MPA.<sup>15,19</sup>

Only few reports described the use of the MPAP flap for plantar foot sole reconstruction.

In this article, which covers a period of 13 years, we describe our experience with the use of the MPAP flap for soft tissue defect reconstruction of the heel, the middle part of the foot sole, and the forefoot plantar region.

During the flap elevation we could always identify, in the septum between the abductor hallucis and the flexor digitorum brevis muscle, two perforators: one proximal, few centimeters after the exit of the MPA from the abductor hallucis muscle, and one more distal. However, the caliber of the perforators could be variable (around 0.4 to 0.8 mm); in 24 cases the proximal perforator was bigger than the distal perforator and the flap could be harvested based on only one perforator. In two cases (two heel reconstructions) 2 perforators were included in the flap because the distal perforator appeared dominant with a bigger caliber compared to the proximal one. About the forefoot defect, the distal perforator was the one to supply the vascularity of the pedicle MPAP flap. Usually a few cm distally to the distal perforator of the superficial branch of the MPA, perforators, that runs from the superficial branch of the MPA up to the dorsal foot, can be appreciated; these are the connecting branch

from dorsal to plantar foot and should be always spared and kept if a distal based MPAP is planned.

Based on our experience, the selection of the perforators depends on the intraoperative findings: 1) for heel reconstruction the proximal perforator is the more suitable due its vicinity to the defect; however, if it has very small size, the second perforator can be included as well. 2) for middle plantar foot reconstruction actually the dissection of the MPA is less important than heel construction as the MPAP flap needs to be rotated in propeller fashion of around 90 degrees, and it is possible only by dissecting the proximal or distal perforator. The choice of the perforator depends on the its size. In our series in all four cases the proximal perforator was selected.

3) for forefoot plantar reconstruction between the first and third metatarsus, our first choice is the distal perforator of the MPA; however, if it is not to be trusted due to its very small size, the proximal perforator can be included. We usually tried to dissect only the perforator and to propeller the flap without divided the superficial branch of the MPA proximally, however sometimes it was not enough to reach the defect, and consequently we needed to dissect the superficial branch of the MPA and eventually to divide it proximally to gain more length. Before dividing it proximally, we always clamped temporarily the vessel proximally and checked the vascularity of the flap for few minutes. If no signs of congestion appeared, we proceeded with the division.

In contrast, for forefoot plantar reconstruction between the third and fifth metatarsus, we proceeded for a free MPAP based on one dominant perforator.

Comparing with the instep flap, the MPAP flap has no fascial component and can be based on 1 or 2 perforators allowing an extra propeller rotation with consequent increase of the pedicle length if necessary.

About the flap donor site, it interesting to mention that our patient did not experienced early and late complications of the donor site area such as split-thickness skin graft loss, infection,

and contracture and pain; it might be due to the preservation of the fascia; however further investigations are warranted to address this point.

Patient selection is an important aspect to achieve favorable results: the Doppler of the PTA, DPA and of the perforators of the superficial branch of the MPA were routinely performed in all our patients before the reconstruction, only if the indicators were positive the patient was selected for MPAP flap reconstruction. Certainly, patients that have no PTA nor DPA pulse, nor with diabetes nor a vascular disease should be considered to be at risk and not be a good candidate for this reconstruction procedure. The patients' venous condition was investigated as well and none of our patients had venous incontinence.

The limitation of the MPAP flap is that it is not suitable for the repair of a big defect involving more than two third of the plantar foot, our biggest flap was  $5.5 \times 9.5$  cm, which actually represents the whole instep area. However, it is usually big enough for middle and small defect coverage.

In contrast the MPAP flap has several advantages: 1) optimal flap thickness and quality for plantar foot reconstruction, 2) good color and texture match, 3) minimal donor site morbidity, 4) lack of functional loss, 5) wide arc of rotation, 6) consistent and reliable vascular anatomy, 7) possibility of a sensible flap including the cutaneous nerve of the medial plantar nerve.

## **Conclusions**

In summary, the MPAP flap can be elevated based on the perforators of the superficial branch of the MPA. The perforators location is constant and allows a proximal or distally based flap. The donor site morbidity is minimal. Furthermore, the MPAP flap can be used as a pedicle or free flap, and in both cases as a sensate flap as well. Our case series shows that the MPAP flap is an ideal and optimal method for covering small to medium size defects of the heel, middle foot sole and forefoot plantar region.

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## Figure Legend

Figure 1: the perforators of the superficial branch of the medial plantar artery (MPA) can be identified through the intermuscular septum between the abductor hallucis muscle and the flexor digitorum muscle. Arrows: proximal and distal perforators of the superficial branch of the MPA; star left: posterior tibial artery (PTA); dot middle: superficial branch of the MPA; triangle right: abductor hallucis muscle.

Figure 2: Range of applications of the MPAP flap with two constant perforators of the superficial branch of the medial plantar artery: Example A shows a defect in the forefoot area. The flap is rotated 180° and therefore, the blood supply comes retrograde from the dorsalis pedis artery. Example B shows a defect of the midfoot. The flap needs to be rotated 90° from the harvest site. Example C shows a defect of the heel. In order to cover the defect, the superficial branch of the medial plantar artery is tracked proximally until a sufficient length is needed for flap rotation. Triangle: superficial branch of the MPA, star: deep branch of the MPA.

Figure 3: Defect measured 5 cm × 5 cm after wide excision of the Melanoma in the left heel (above left). A 5 cm × 5 cm pedicle MPAP flap was harvested from the ipsilateral instep area based on one perforator (above right). The MPAP flap was transferred to reconstruct the defect and the donor site was covered with split-thickness skin graft from the contralateral thigh (below left). Follow-up at 6 months post-operative (below right).

Figure 4: Defect measured 6 cm × 5 cm after wide excision of the Melanoma in the right middle foot sole (above left). A 6.5 cm × 5.5 cm pedicle MPAP flap was harvested from the ipsilateral instep area based on the proximal perforator (black arrow) (above right). The MPAP flap was propelled 90 degrees to cover the defect and the donor site was covered with split-thickness skin graft from the contralateral thigh (below left). Follow-up at 8 months post-operative (below right).

Figure 5: Defect measured 4 cm × 4.5 cm after wide excision of the Melanoma in the right plantar forefoot (above left). Dissection of the distal MPAP perforator (above right). A 5 cm × 5 cm pedicle MPAP flap was harvested from the ipsilateral instep area based on the distal perforator (below left). The MPAP flap was propelled 180 degrees to covert the defect and the donor site was covered with split-thickness skin graft from the contralateral thigh (below right).

ACCEPTED



**Table. 1** Summary of the patients receiving MPAP flap for Heel, middle part and forefoot reconstruction

No.	Age/Sex	Etiology	Defect location	Size Defect (cm)	Type of MPAP-flap	No. of Perforators	MPAP harvest ing time (min.)	Follow up	Complication
1	55, W	Ulcer	Heel	5 x 5	proximal pedicle based	1 P	45	12	none
2	65, M	Tumor	Heel	5 x 4.5	proximal pedicle based	1 P	55	8	none
3	31, M	Ulcer	Heel	7 x 4	proximal pedicle based	1 P	60	12	none
4	56, M	Tumor	Heel	2,8 x 3	proximal pedicle based	1 P	45	6	none
5	83, W	Tumor	Heel	3.5 x 4	proximal pedicle based	1 P	50	6	none
6	63, M	Tumor	Heel	3 x 3	proximal pedicle based	1 P	40	9	none
7	63, W	Tumor	Heel	4 x 2	proximal pedicle based	1 P	45	12	none
8	56, M	Ulcer	Heel	4 x 5	proximal pedicle based	1 P	55	12	none
9	37, W	Ulcer	Heel	5 x 3	proximal pedicle based	1 P	50	12	none
10	84, M	Tumor	Heel	5.5 x 9.5	proximal pedicle based on	2 P + D	60	9	none
11	80, W	Ulcer	Heel	3 x 4	proximal pedicle based	1 P	45	9	none
12	37, M	Ulcer	Heel	6 x 5	proximal pedicle based	1 P	60	4	none
13	73, M	Tumor	Heel	4 x 4	proximal pedicle based	1 P	65	12	none
14	52, W	Ulcer	Heel	3 x 4.5	proximal pedicle based	1 P	50	12	none
15	22, W	Trauma	Heel	5,5 x 5,5	proximal pedicle based	1 P	45	6	none
16	70, W	Tumor	Heel	4 x 3	proximal pedicle based	1 P	60	12	none
17	48, M	Tumor	Heel	5 x 4	proximal pedicle based	1 P	55	8	none
18	12, W	Trauma	Heel	6 x 7	proximal pedicle based	2 P + D	60	8	none
19	63, M	Ulcer	Heel	7 x 5	proximal pedicle based	1 P	55	12	none
20	44, W	Tumor	Heel	5 x 5	proximal pedicle based	1 P	55	4	none
21	19, W	Tumor	Medial	5 x 5	proximal pedicle based	1 P	55	4	none
22	68, W	Tumor	Medial	7 x 5	proximal pedicle based	1 P	60	12	none
23	47, W	Tumor	Medial	4 x 4	proximal pedicle based	1 P	55	6	none
24	51, M	Tumor	Medial	6 x 5	proximal pedicle based	1 P	55	9	none
25	53, W	Tumor	Forefoot	2,5 x 2,5	distal pedicle based flap	1 D	75	9	none
26	73, W	Tumor	Forefoot	3 x 4,5	distal pedicle based flap	1 D	80	12	total lost
27	60, M	Tumor	Forefoot	5 x 4	free flap	1 P	60	6	none
28	58, M	Tumor	Forefoot	5 x 6	free flap	1 P	55	8	none

Figure 1

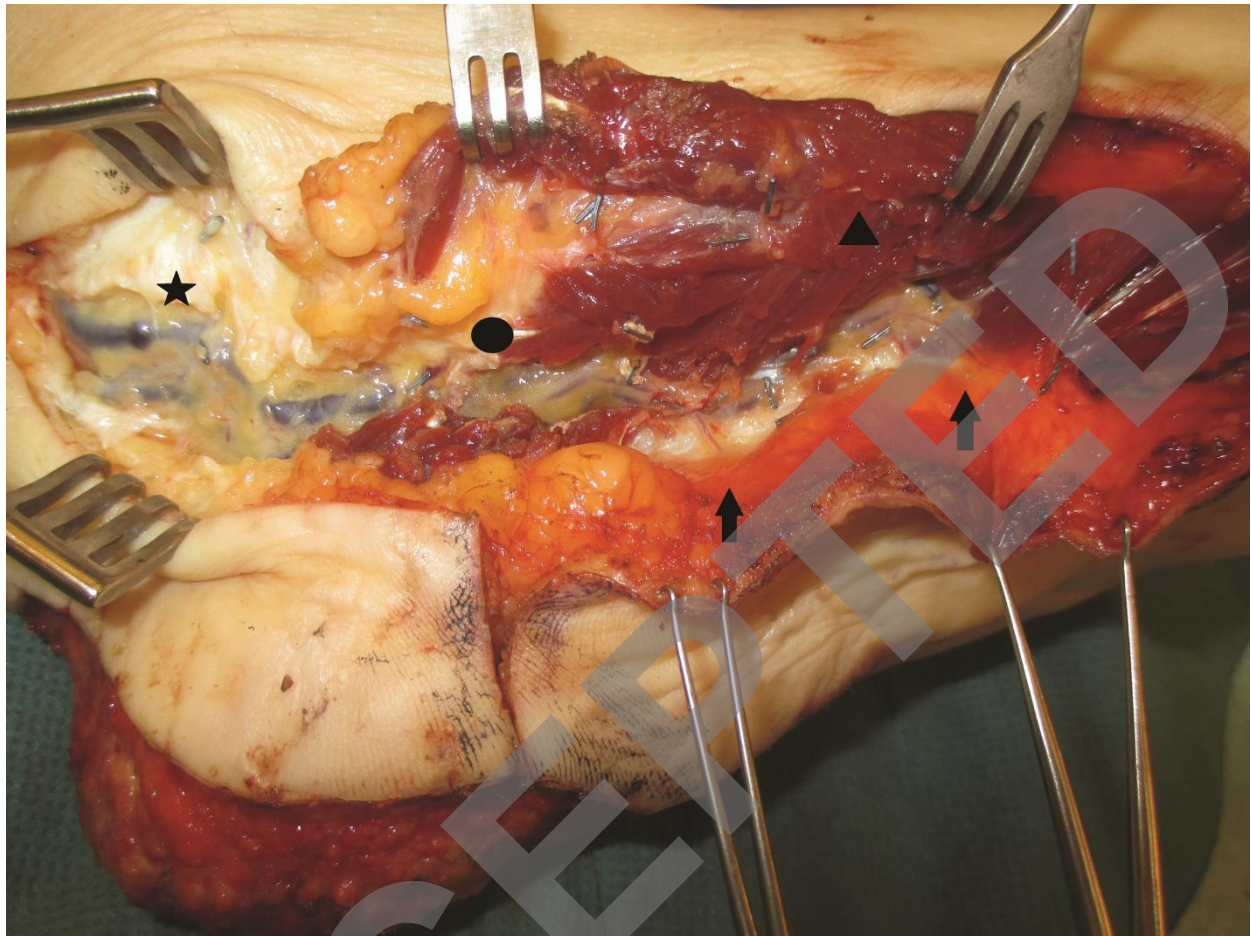
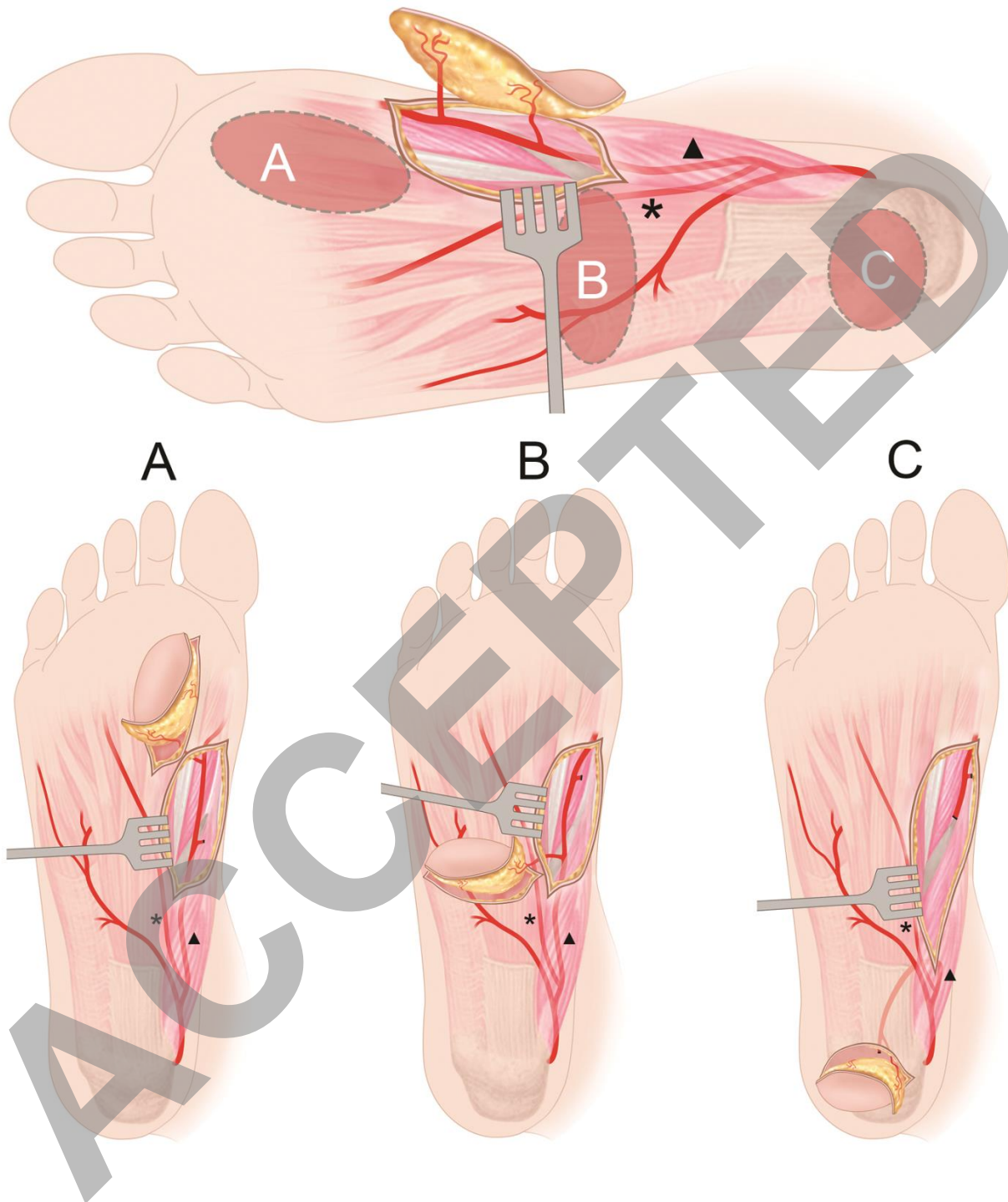


Figure 2



**Figure 3**

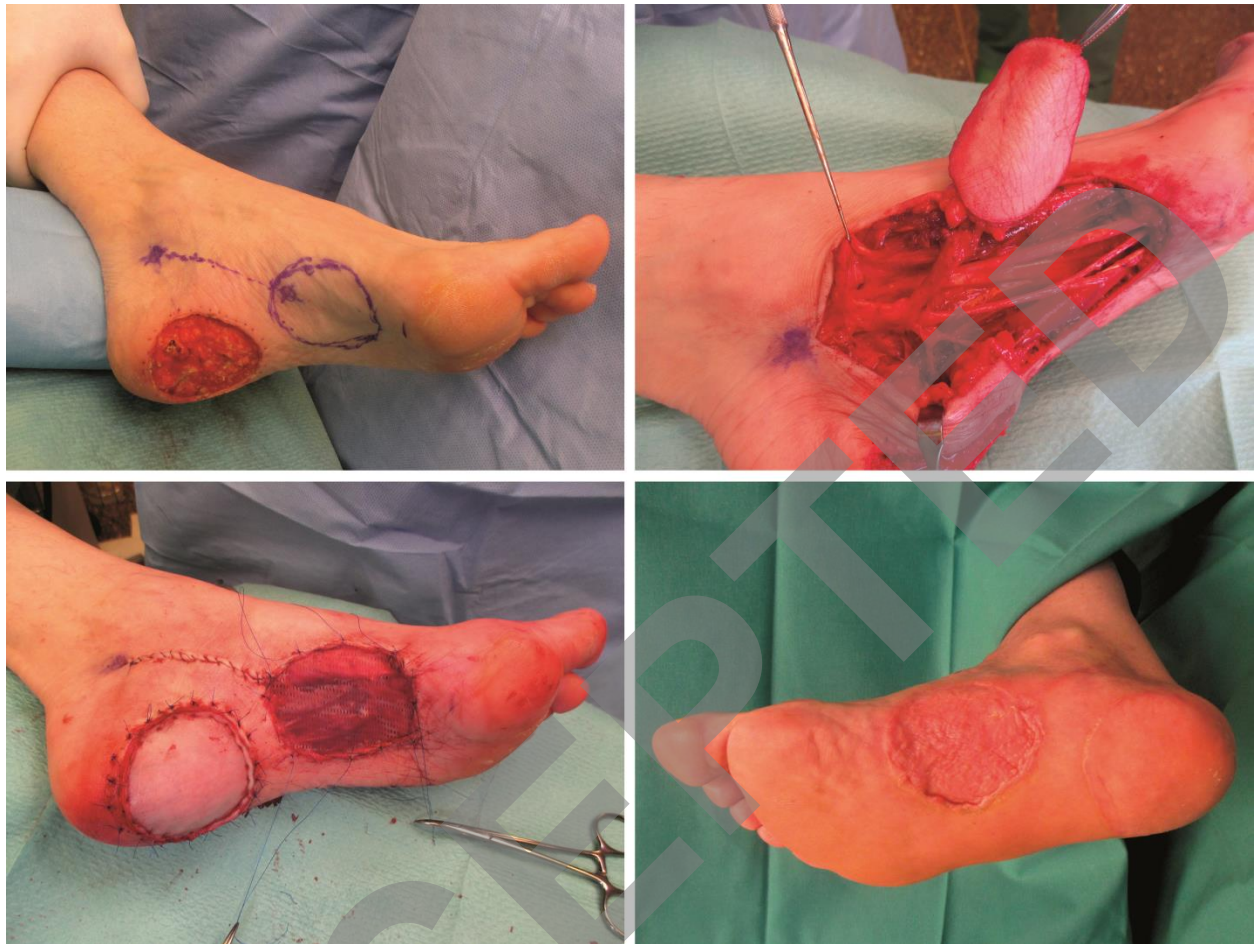




Figure 4



Figure 5

